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Improvements
to
Main Injector RF

Ralph J. Pasquinelli
2/25/04

▌ *Multiple modes of operation with same hardware*

    ▌ *Slip Stacking*

    ▌ *2.5 MHz pbar acceleration*

    ▌ *Five batch operation for NuMI*

    ▌ *Fixed target operations SY 120*

    ▌ *Coalescing*

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System Requirements

- _Beam loading/Feed forward compensation_
- _Maximum voltage for acceleration_
- _Zero volts for 2.5 MHz pbar acceleration_
- _Programmed volts for coalescing_
- _Two frequency operation for Slip Stacking_

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Figure 9. Amplifier Quote

Solid-State Amplifier Quote $477K for 80-1 KW units

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Figure 10. 8 rf modules in standard relay rack with 8 way combiner.
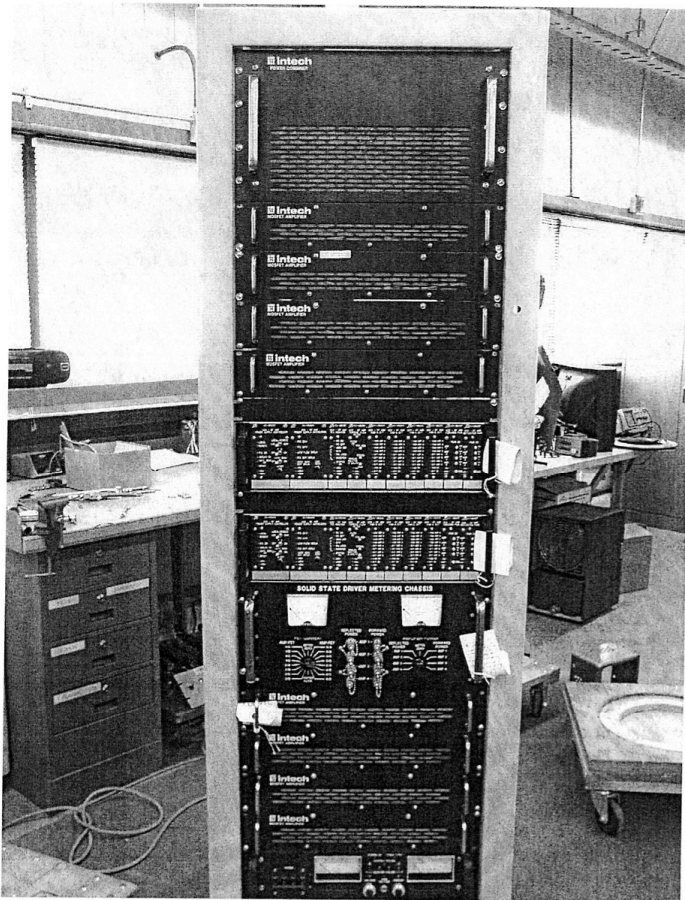
*Modified Solid State
Amplifier Relay Rack
Now operational in Station 2*
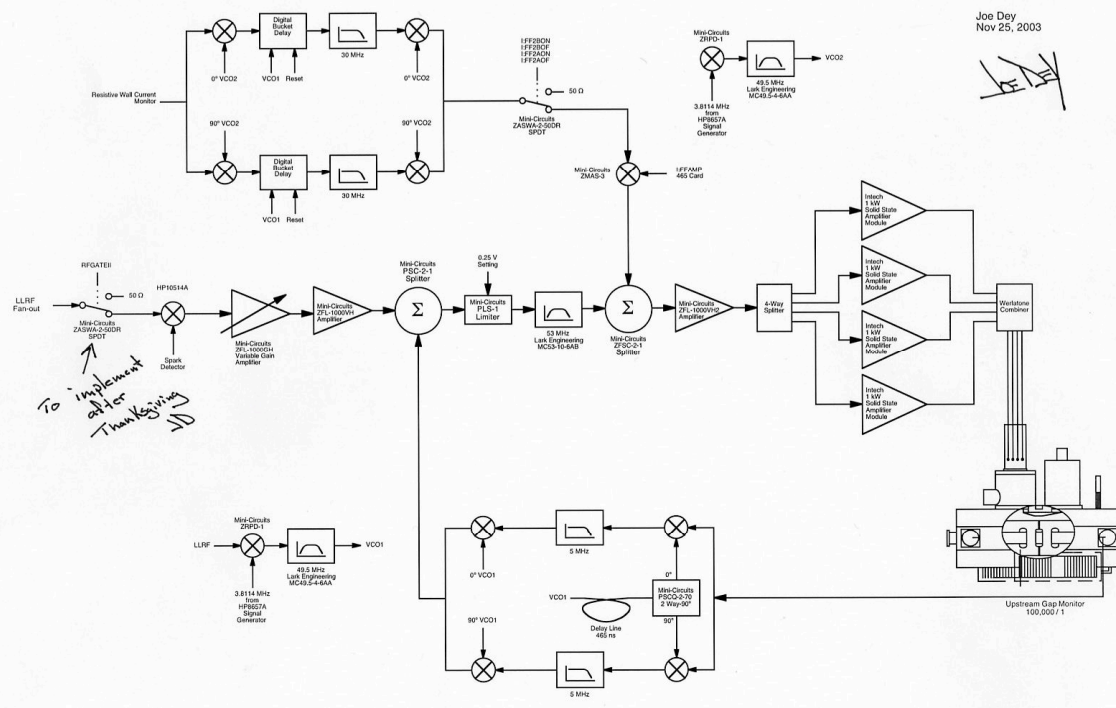
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49 MHz feedback and feed forward Block Diagram
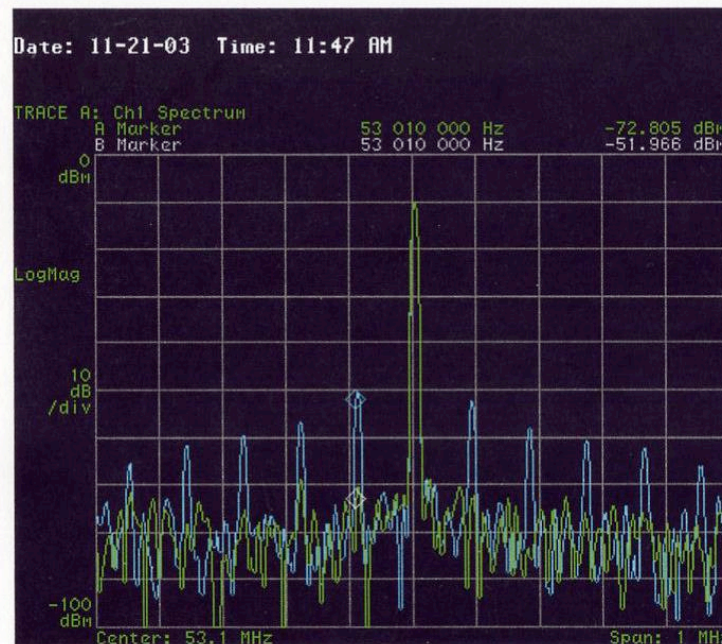
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Main Injector RF

Suppression of revolution harmonics with 49 MHz feedback/feed forward now operational on all 18 stations
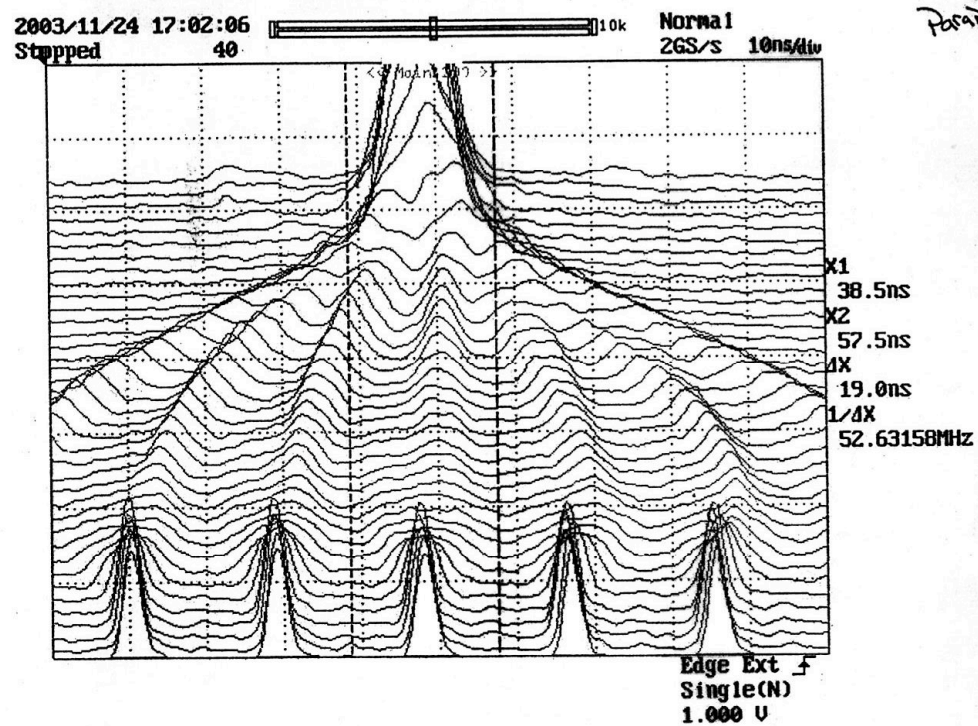
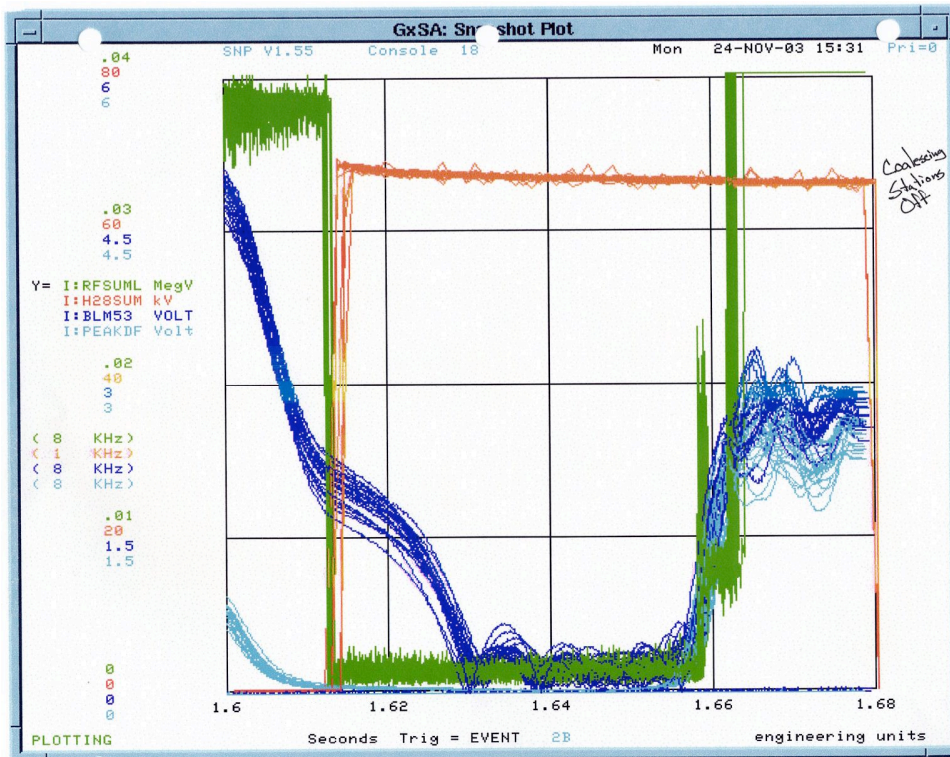
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Coalescing with Paraphasing

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Coalescing with Stations Off

Green 53 MHz Sum
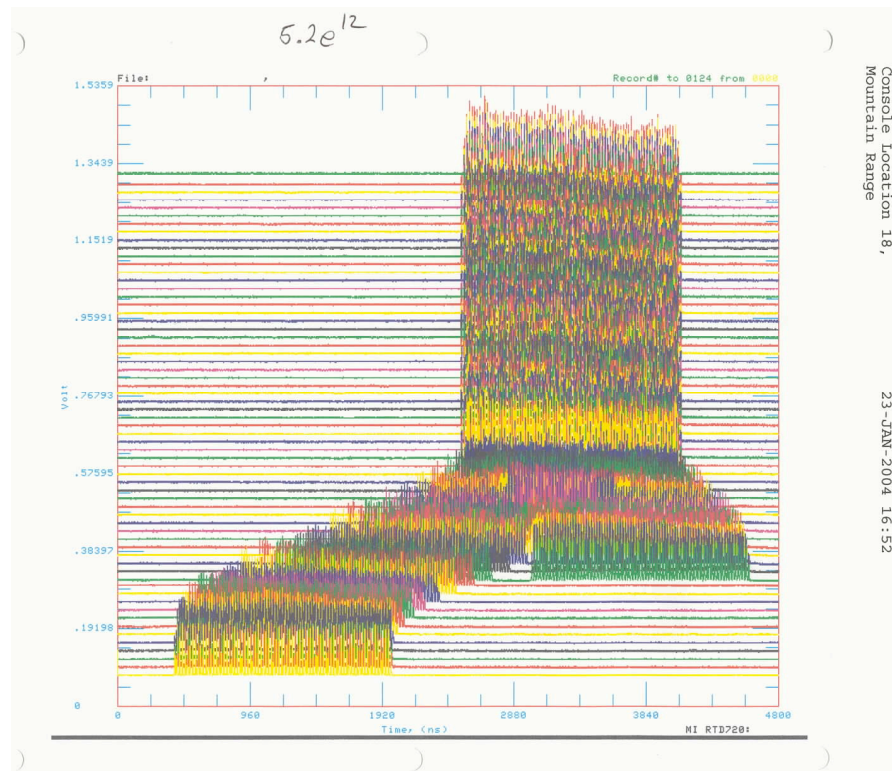*Red 2.5 MHz Sum*
Dk Blue Bunch Length

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Slip Stacking with 5.2x10^{12} protons

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High Level RF Model

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Amplitude Control by Vector Angle Modulation

$V_{rfABprg}$

RF1

ϕ

V_{rf_prg}

RF2
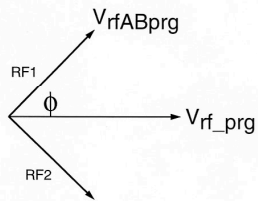
$V_{rf\_prg} = 2 \times V_{rfABprg} \times \cos(\phi_{rf2} - \phi_{rf1})$

Medium Level RF (MLRF)
Vector Diagram

Ay

ϕ

Ax

$V_{rfABprg}$

Az
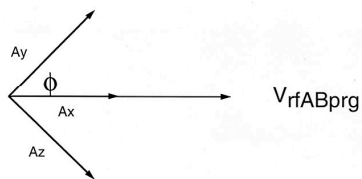
$V_{rfABprg} = Ax + (Ay + Az) \bullet \cos(\phi_{Ay} - \phi_{Ax})$

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Middle Level RF Vector Amplitude Control H588

High Level RF Vector Amplitude Control H588

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Advantages of this Topology

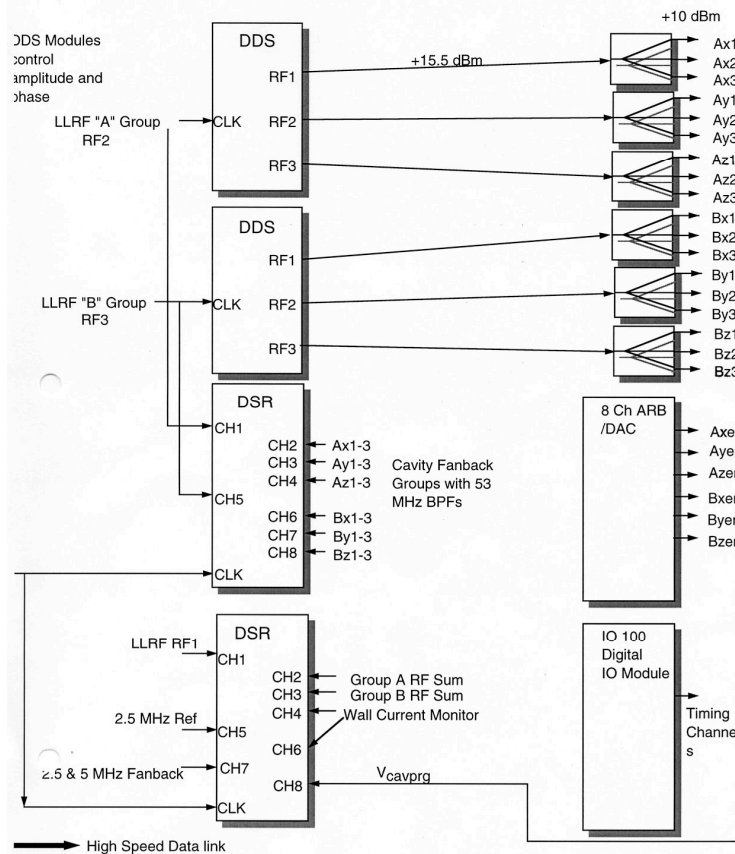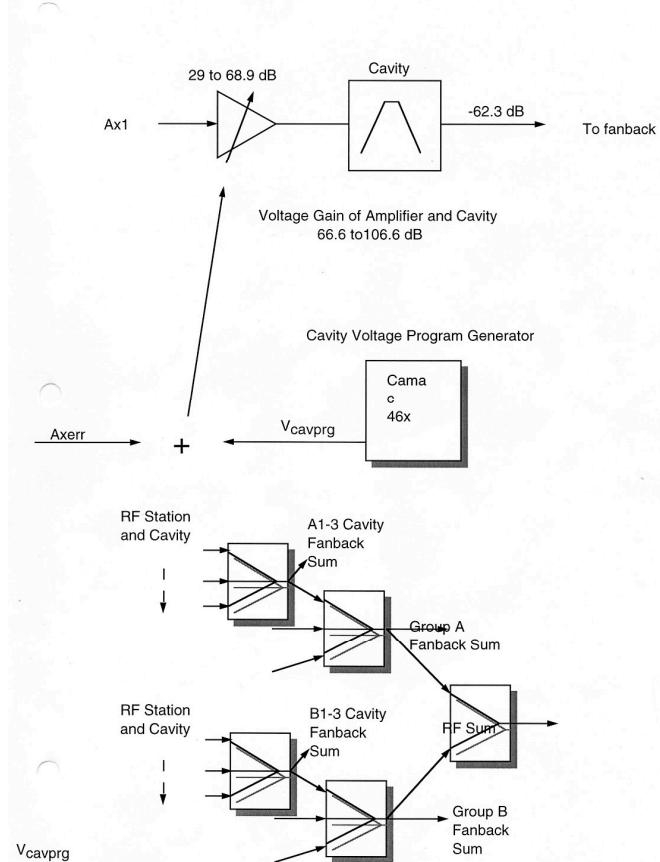- *There are no "special" stations that will stop operation on a single point failure*
- *Vector control may rely more on phase and less on amplitude as any vector may be created without 180 degree angles between vectors. For example, three equal amplitude vectors at 120 degrees sum to zero volts. Any error voltage may be nulled by changing the angle of two of the vectors.*
- *This configuration will allow all the stations to be on at some reasonable level during processes like slip stacking. The PA tube may then be biased to a lower DC current, greatly reducing power consumption while maintaining small signal gain and linearity.*
- *Symmetry in the station grouping is conceptually cleaner and makes the hardware and software design cleaner as well.*

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Fermilab *Main Injector RF*

- *Project start 11/1/03*
- *Vector controller design topology defined 1/1/04*
- *All HLRF hardware is on order, LLRF hardware in house*
- *Hardware and software for vector controller assembled, including new VXI and fanback box 6/1/04*
- *Installation of LL hardware 7/1/04*
- *Staged installation of HL hardware 4/04-7/04*
- *Testing of system with/without beam 7/15/04*
- *Testing of slip stacking with beam before summer 04 shutdown*
- *Testing of 2.5 MHz acceleration of pbars before 04 shutdown*

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